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THE INSTITUTE OF THEORETICAL ASTROPHYSICS
OSLO UNIVERSITY, NORWAY

SUMMARY REPORT FOR THE PERIOD
1/1 1959 TO 31/12 1960 UNDER CONTRACT AF 61 (052) - 186

"RESEARCHES IN THE FIELD OF SOLAR RADIO NOISE, SUNSPOTS, PROMINENCES AND FLARES"

CATALOGED BY ASTIA AS AD NO.

by

THE STAFF OF THE INSTITUTE

The researches reported in this document have been sponsored by the Geophysics Research Directorate of the Air Force Cambridge Research Laboratories, Air Force Research Division, under Contract No AF 61(052)-186 through the European Office (EOARDC) in Brussels, Belgium.

Oslo, January 21, 1961

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I. INTRODUCTION

The studies reported in the following were undertaken by the staff of the Institute of Theoretical Astrophysics and the Solar Observatory during the period 1 January '59 to 31 December '60. The scope of the investigations was set by the statement of work in the ARDC Contract No AF 61(052)-186 as of 1 December 1958:

> 1. "Studies will be made of variable solar phenomena based on observations obtained with the 200 mc radiometer and the 200 mc interferometer in connection with the double channel burst analyzer. Emphasis will be placed on the study of noise storms, frequency drifts, and intensity variations with respect to frequency of noise storm bursts.
>
> 2. Studies will be made of optical solar phenomena based upon data obtained with the solar tower telescope and the Zeiss Coudé solar telescope and shall comprise: (a) Sunspot studies using a pinhole photometer, heliograph camera and horizontal spectrograph. (b) Studies of solar prominences and flares using the Zeiss Coudé telescope and spectroheliograph."

The above statement of work was modified in "Supplementary Agreement No 1" as of 10 December 1959 by adding

> 3. "Observations will be made of solar noise storms, and the information obtained will be analyzed for contributions to knowledge of the interrelation of the observed phenomena. (a) The fine structure of radiation in the 200 mc band will be observed using sweep-frequency receivers. Flux observations will be made at 200 mc using the Dicke radiometer. Interferometric observations will be made of associated active solar areas. (b) Observations will be made of umbra intensities in associated sunspots using a pinhole photometer in connection with the tower telescope. (c) Methods will be devised for accurate timing of associated solar flares observed with an H_α-filter for study of time relations between noise storms and flares."

The conduction of the research has generally speaking followed the principle of least resistance. In some cases promising lines of research had to be put in abeyance because of changes in the staff, or instrumental shortcomings, while in other cases new ideas led to the adoption of new, apparently more promising problems. This state of things is reflected in the titles of the scientific reports written, and partly also printed, up to the present stage of the contract period. The various reports are mentioned in the text, and in addition given in a list at the end of this report.

II. SOLAR RADIO NOISE

1. Burst analysis

In the "Statement of Work" main emphasis is placed on the further development of burst analysis as it was initiated under the preceding contract and reported on in the corresponding Technical Final Report of January 21, 1959. The new feature of burst analysis carried out under the current contract consists in the use of a new receiver permitting continuous registration over a frequency band centered on 200 Mc/s. The band width can be varied from a few Mc/s up to 30- 40 Mc/s.

This new instrument was constructed in the shop by Eriksen and Elgaröy during the early part of 1959 and put into operation by Elgaröy in July 1959. In the beginning of the work this spectrometer was attached to the Würzburg antenna. In as much as this interfered with the normal registration of 200 Mc/s radiation, a helix antenna was mounted on the 57 Mc/s mattress antenna and used in conjunction with the swept frequency receiver. Such an arrangement had, of course, the disadvantage to work with a low power level, but appeared to be the best compromise under the circumstances, when it was of overall importance to get observations going as early as possible. The main advantage of the new receiver over other swept frequency receivers in use elsewhere consists in the high speed and consequent high resolution of the registrations, permitting a much clearer insight into the processes at work on the sun. On the other hand, the high speed makes the receiver costly to operate as it consumes film at a very high rate, so that careful judgment must be exercised about the right time to put it into operation.

The instrument appeared successful from the start in that highly interesting registrations were obtained already in August, showing clean drifts of bands across the spectrum, or complicated patterns, exhibiting fine symmetry properties. These results appeared so interesting that they were reported immediately to "Nature" in a letter to the Editor:

"OBSERVATIONS OF THE FINE STRUCTURE OF ENHANCED SOLAR RADIO RADIATION WITH A NARROW BAND SPECTRUM ANALYZER",

printed in the September 19 issue of the journal.

Since then, Elgaröy has continued observations with the narrow-band spectrometer, which has been redesigned and modified for better performance. He has collected a large amount of material, and during 1960 he has spent most of his time analyzing the material and preparing a comprehensive, overall report. This work was completed in the late fall, and took the form of

a monograph of somewhat more than 100 typewritten pages and 94 figures. It was given the title

"HIGH RESOLUTION SPECTROMETRY OF ENHANCED SOLAR RADIO EMISSION"

and presented to the Academy in the session of November 18, 1960. It is expected that the paper will appear in print sometime in the spring of 1961.

The main points brought out by these researches are the following:

1. The dynamical spectra of type I bursts do not form a single homogeneous class, but must be divided into sub-classes.

The frequency of occurrence of bursts of different sub-classes were determined from representative noise-storm records, and lifetime, bandwidth and line profiles of type I bursts were studied.

2. Observational evidence of echo-effects were presented.

3. Examples were shown of bursts that are split into two components with a frequency separation of about 8 Mc/s. This may be the same type of splitting known earlier from bursts of spectral type II, i.e. "outbursts".

4. Theories proposed to explain type I storms were reviewed and compared with observations, and some interpretations of the sweep-frequency observations were proposed. Arguments were advanced in support of the view that type I bursts are generated by a sporadic emission process with energy output in a narrow frequency band, as opposed to the earlier suggestions that bursts are caused by variable transmission or focusing of radiation from a wide-band source.

5. Attention was drawn to examples of solar registrations with a peculiar structure, and possible interpretations were discussed.

6. High-resolution spectra of type III bursts recorded at our observatory were compared with wide-band spectra obtained simultaneously at the Harvard Radio Astronomy Station. The agreement was found to be satisfactory.

7. Evidence was presented of the existence of fine structure in type III bursts.

8. It was shown that it seems possible to account for details of type III burst spectra on the basis of current theory for this class of solar events.

2. Base level variations

During the report period the Dicke radiometer has been in operation during the ten-month periods 1 February to 1 December, the months of December and January being excluded because of low solar altitude that creates troublesome ground reflections.

The registrations have been analyzed by Hauge for variations in the solar base level, and his results were reported in a paper:

"VARIATIONS IN THE SOLAR BASE LEVEL RADIATION ON 200 Mc/s".
8 pp and 3 figs. Astrophysics Norvegica Vol. VI, No 11, January 1960.

In this paper Hauge discussed all available material from the observatory bearing on the emission of thermal radiation on 200 Mc/s, and found marked variations indicating that the radiation intensity at sunspot maximum is about twice that of sunspot minimum.

3. Interferometer observations

The 200 Mc/s interferometer has been kept in operation by Maltby since February 1958. It consists of two identical mattress antennas spaced 136.73 wavelengths apart on an east-west base line. The position of a source in the solar atmosphere may be determined from the record with an uncertainty not exceeding 0.75 minutes of arc. The state of polarisation is obtained by using an orthogonally polarized antenna in addition to the interferometer antennas.

Observations, begun in 1958, were continued all through 1959, and a summary of the results is in existence as a manuscript by Maltby to be published in a joint paper from several staff members, which will appear as "Report No 12" from this Institute. In this paper the observed position lines of sources are plotted on charts from the "Daily Maps of the Sun" as published by the Fraunhofer Institute. The position lines correspond to the moment the sun crosses the local meridian, i.e. about 1115 U.T. .

A comparison between the positional determinations made at the Nera Station of the Netherlands PTT (255 Mc/s) and the Oslo Solar Observatory showed that the observations were in close agreement, taking the difference in frequency into account.

On several occasions two or more sources are simultaneously present in the solar atmosphere. The observed position will then be a weighted mean of the position of the active sources. A case was noted when a vanishing amplitude of the interferometer record was obtained, though two sources were present on the disk, the vanishing being due to signal destruction by mutual interference.

Analysis of the results indicated that 30 per cent of noise-active sunspots (62 in all) were associated with more than one noise storm.

4. Origin and decay of noise storms

Maltby undertook a discussion of available material in its bearing on the possible presence of an east-west asymmetry in the origin and decay of solar radio noise storms. Such asymmetry was earlier discovered for sunspots, flares and flare-associated radio outbursts. The results of the investigation were published in a paper:

"DISTRIBUTION OF ORIGIN AND DECAY OF NOISE STORMS ON THE SOLAR DISK", Astrophysica Norvegica, Vol. VI, No 13, 1960.

The main results of the investigation was that noise storms decay on the western half. The analysis was based on data from the Nera Station of the Netherlands PTT and our own radiometer observations.

An attempt was made to explain the observed asymmetry in start and decay in terms of the limiting iso-diaphanous surface and the angular emission diagram of the radio source. It was concluded that an asymmetry in the observed noise storms on the disk indicates that the angular emission diagram of the radio source is not perpendicular to the solar disk.

5. Noise storm - umbra correlation

It is generally accepted that enhanced solar radiation on meter wavelengths originate in the solar atmosphere above a group of sunspots. This leads to the supposition that the existence of spots or spot groups is a necessary condition for the emission of excess radiation. As only a few sunspots are associated with noise storms the question arises which phenomena connected with spots are important for the simultaneous production of radio noise. If such characteristic features of noise-active spots could be found, we might be a step further on the way to an understanding of the mechanism of noise generation. This problem has been discussed by various authors and from different points of view. The problem was re-examined under the present contract by Maltby for the special case of correlation between noise storms and the radiation intensity of associated sunspots as determined by Ofstad using the pinhole photometer. Maltby found definite indications of the existence of a threshold value for the umbra intensity above which no correlation with noise storms were found. Below the threshold the correlation is surprisingly high. These findings were reported to "Nature" in a letter to the Editor:

"CORRELATION BETWEEN THE INTENSITY OF THE UMBRA OF SUNSPOTS AND ENHANCED RADIATION ON 200 Mc/s",

printed in the issue of October 31, 1959.

Identifications were based on interferometer data from Nera, Netherlands, and Oslo Solar Observatory. The observations were made between January 1956 and October 1959. Noise storms with flux density less than $1.5 \times 10^{-21} Wm^{-2} (c/s)^{-1}$ were omitted. Magnetic data were obtained from Mount Wilson observations, and spot areas from Crimean data. Relative intensities of umbrae and penumbrae in spots were obtained from Oslo Observatory observations, where such data were obtained by means of a pinhole photometer.

The main novel result of this investigation was the discovery of a pronounced connection between the darkness of umbrae and noise storms. The correlation is significantly higher than was found for other sunspot properties. It is strongly indicated that for a spot to show noise activity the intensity of the umbra of the spot must be smaller than a threshold value of about 20 per cent of the disk intensity at a wavelength of 5500 Å. The same result is obtained in other wavelength regions (4250 Å and 7500 Å).

An inspection of Mount Wilson records yields no real unipolar group of spots showing noise activity. Because of the limited material available no more definite conclusion can be drawn as to whether noise-active spots must be bipolar or not.

The occurrence of a noise storm or flare seems to depend on the development of the spot. It was found that the chance of observing the start of a noise storm is highest when the area of the sunspot is rapidly increasing. Another aspect of the same phenomenon was the finding that 70 per cent of the noise storm starts discussed took place when the number of spots in the group was increasing.

III. INVESTIGATIONS ON SUNSPOTS

The sunspot problem has been under constant attack in the report period, partly from the observational side and partly, and most actively, by analysis of observational material available from outside sources.

The "Statement of Work" mentions specifically observations with the pinhole photometer and the Zeiss Coudé telescope. Both lines of research have been pursued as far as observing conditions have permitted, but the problems have proved to be particularly knotty, and no reports are as yet available in manuscript form. For this reason the problems are both carried over into the extension of the contract for 1961. In the following a general report on the status of both problems will be given as of the end of 1960.

1. Pinhole photometry of sunspots

The pinhole photometer was built in the radio shop by Eriksen and tried out by Jensen in 1958. In the present report period the observational duties were turned over to Ofstad, who has been in charge of this program ever since. The observations have been done in three different colors centered on the wavelengths 3500 Å, 4500 Å, and 7500 Å. Main purpose of the program was to get a long series of observations to see whether the intensity distribution in a spot changes systematically during its life-time, or at different phases of the solar cycle. During the first half of 1959 Ofstad got usable material from 30 spots, involving 250 individual observations. It was about this stage that the comparison of pinhole data with noise-storm data led to the discovery of the threshold value of umbra intensities for noise generation by Maltby as mentioned in II.5 above.

The observations have been continued, and are still going on, though the material grows only slowly, partly on account of declining solar activity, but mostly because of the exceptionally unfavorable weather in the summer of 1960. In as much as the reduction of the registrations is a slow process, this fact may not be so bad, as it has given Ofstad the time to keep the reduction process abreast with the accumulation of observational material. The final report on this work will definitely be given during 1961.

2. Accurate timing of flare phenomena

This problem was initiated by Brekke, who suggested to run the film of the Zeiss Coudé instrument at a continuous speed at times when flares might be expected to occur. The H_α-filter would, of course, be operating.

The film should be provided with suitable time markings along the edge, and it should be stopped at intervals to record ordinary H_α-pictures of the solar disk. With suitable adjustment of the film speed one might then think it possible to register the flare as a long dark band on the film, and with the beginning and the end of the flare precisely marked in time. In as much as the noise storms are fairly well timed by the Dicke radiometer, a close comparison of the beginnings of the two associated phenomena should be possible.

It was at first thought necessary to procure a second Lyot filter for the testing of this idea. But it was soon shown by Eriksen that a simple sort of attachment to the existing setup should be satisfactory for exploratory work. Eriksen had the attachment made in the shop and preliminary tests with the modified instrument were done in the early summer of 1959. In as much as the accurate timing promised by this setup seemed to be definitely superior to material otherwise available, it was decided to push this program vigorously for some time, and Brekke was put in charge of the job.

Thus far the results of this work has been frustrating - to say the least. During the past year the flare-timer was run for 140 hours to determine the proper density of the neutral filter required in front of the camera, and to establish a suitable development process. But the intensity variations in the sunlight (due to atmospheric extinction) and the difficulty of getting the monochromatic filter stable at the center of H_α caused considerable trouble. In fact, only two H_α-flares were clearly identified on the records during this work, and both appeared on days of drifting clouds, preventing registration of the starting moment of the phenomenon.

In spite of all these vexatious difficulties we think the problem of such superior interest that we intend to pursue it during 1961 in the hope of finally mastering the technique.

3. Relation between sunspot magnetism and areas

Much work has been dedicated to the problem of sunspot magnetism in the report period, but it has been realized that theoretical investigations will necessarily remain insecure as long as the observational material remains uncertain and spotty - which is still the case. As a modest step in the direction of getting the most out of existing material an agreement was reached with the Mount Wilson Observatory that this institute should get all available Mount Wilson data for free use.

The reduction of this material in connection with necessary data from the Greenwich Photoheliographic Results was performed by Ringnes and Jensen. The numerical work involved proved to be very time-consuming, and the final paper was only sent to the printer in the fall of 1960. The title of the paper is

"ON THE RELATION BETWEEN MAGNETIC FIELDS AND AREAS OF SUNSPOTS IN THE INTERVAL 1917 - 1956."

It is to appear as No 4, Vol. VII, of Astrophysica Norvegica, and is expected to appear in print in the next months.

The main results of this paper may be summarized as follows:

1. Three forms for the analytical relationship between magnetic field and area of a spot are used for the analysis of the data. The first is the form proposed by Houtgast and van Sluiters, the second is

$$H = a.\log A + b,$$

and the third is

$$H = c.A^{\frac{1}{4}} + d$$

where H is maximum magnetic field strength, A is area (of umbra or penumbra) while a,b,c and d are certain numerical coefficients. The correlation with observations are best for the logarithmic law and with the umbra area as a variable.

2. No systematic change could be found in the coefficients with phase in the solar cycle.

3. Very pronounced secular variations were found in that spots of small og medium size have a smaller magnetic field strength for its area in the later years than in the early years of the interval under investigation.

For the largest spots the opposite is true.

4. Miss Bell's statistics on the frequency of spots with large fields (Publ. Astr. Soc. Pac. 71,165,1959) receive a simple interpretation in the light of the present results. The agreement is remarkably good and must mean that the behavior of all spots is of the same nature as that of single regular spots covered by this analysis.

5. The difference in relative number of recurrent spots from cycle to cycle may also be understood from these results on assuming that in case of two spots with equal area the one with the larger magnetic field also has the longest lifetime. Such a comparison was carried out in detail for the intervals 1917-24 and 1945-54.

6. The pronounced difference in relative numbers of very small spots in the two intervals 1917-24 and 1945-54 may, it seems, also be traced back to the same cause. This follows if it is postulated that the magnetic field must exceed a threshold value of a few hundred gauss in order that a spot may be formed.

The outstanding result of the investigation is the fact that the H-A relationship is subject to considerable secular changes, a conclusion which seems inescapable. The change has, within the interval investigated, been unidirectional, but this means only that the time scale of variation - whether periodic or erratic - is of the order of a hundred years or so. Whether these changes have any connection with the suggested 80-year period in sunspot activity is thus far an open question.

Systematic changes in the H-A relationship from maximum to minimum solar activity were searched for in vain. Whether there exists a difference between the ascending and the descending branch of the cycle could not be decided from the present material.

4. Correlation between observations from different observatories

It was noted on several occasions that material from different observatories only show moderate agreement, and that a special study of the relationships that exists between the work of different observers would be desirable. Such a study was undertaken by Steen and Maltby of observations of sunspot magnetic fields at the observatories at Mt. Wilson, Potsdam and the Crimea. The results of this study were printed in a joint paper under title

"ON THE CORRELATION BETWEEN OBSERVATIONS OF MAGNETIC FIELDS OF SUNSPOTS AT MT. WILSON, POTSDAM AND THE CRIMEA",

Astrophys. Norv. VI, No 10, 1959.

This paper is a comparative study of a rather scant material, so that too much stress cannot be laid on the results. Correlation coefficients and regression lines were determined for two observatories at a time.

The highest correlation coefficient was found between Mt. Wilson and Potsdam, but even there the correlation is not nearly as good as would be desirable. The differences may be due to different methods of observations and reductions of the results, and serve to strengthen the case for agreements between observatories to ensure comparability of the reduced material when routine observations over long periods of time are called for.

5. Analysis of short-lived sunspots in the interval 1878-1956

The results contained in the paper by Ringnes and Jensen mentioned above (3) suggested the desirability of a more extended investigation of shortlived spots. Such an analysis was undertaken by Ringnes in the fall of 1960, and the work is still in progress. Observational material is available in "Photoheliographic Results" from Greenwich Observatory. From this material such spots were selected as were observed only once. This means that in most cases the lifetime of the spot was less than one day, og at most one day and a half, since Greenwich supplemented outside material with their own observations.

It was found that the number of spots of short duration, the ratio of shortlived spots to total spot number, as well as the frequency distribution of spots with respect to area may vary strongly from one sunspot cycle to the next. Thus it was found that in the interval 1914-24 more than 50 per cent of all observed shortlived spots had areas less than five millionth of the solar hemisphere, while the corresponding figure for the interval 1901-13 was less than 17 per cent.

A pronounced relation was found to exist between the frequency of shortlived spots and the relation between area and magnetic field strength established earlier by Ringnes and Jensen. The relation not only holds for successive cycles as a whole but even for corresponding parts of the cycles, e.g. for half-cycles. Comparing data from 1925-33 and 1945-54 one thus finds that small and medium-sized spots in the latter period have smaller magnetic fields for their respective areas than in the case of the former period. For the largest spots the opposite is true. The case is the same when we consider half-cycles, and compare the interval 1925-28 with 1929-33, and 1949-54 with 1945-48 (i.e. the opposite sense in the two cycles).

An investigation of frequency distribution with area for shortlived spots revealed that the spots are displaced towards smaller areas in 1925-33 compared to the same relation in 1945-54, and also for 1925-28 compared to 1929-33. Other relationships are strongly suspected, though it seems a little early yet to give the precise formulation of such relations.

The relationships discovered so far appear to be of such a clear nature that we may, with considerable confidence, derive a semi-theoretical relationship between magnetic field strength and area also for the three sunspot cycles that fell in the time interval 1878-1913 for which magnetic observations of sunspots were not available, though spot areas were known.

A comprehensive report on these researches by Ringnes will be published as a Scientific Report of the Contract sometime during 1961.

6. Evershed effect in sunspots

The work performed on sunspot structure thus far indicates that the various properties of spots are intimately interrelated, and should be investigated with this idea in mind. It is clearly indicated that important new developments may be expected by well planned, refined and prolonged observations of spot phenomena.

A case in point is the Evershed effect - the low level outflow from spots, indicated by Doppler effects in the spot spectra. The discovery of the close relation between umbra intensity and noise storms by Maltby made him interested in extending the search for new relations to the study of the Evershed effect. For this purpose Maltby started observations of the Doppler displacement of Fraunhofer lines in the spectra of sunspots early in the year 1960. Before his departure to the Owens Valley Radio-Astronomical Observatory in late August '60 Maltby obtained about 1400 spectra from 21 spot groups.

The measurements were made with the large prism spectrograph of the Solar Observatory, the dispersion used being 0.6 Å/mm at 4750 Å. Most of the observations were made on film strips in a small wavelength band about 10 Å wide, centered on 4750 Å. Exposure times: 1/3 to 1/2 second.

The large solar image (D = 30 cm) made it possible to place the slit in different positions relative to the center of the spot with considerable accuracy, and about 20 spectra with different position of the slit were taken of each spot. The position of the slit was found by photographing the spot on a white screen placed before the slit immediately after the spectrum was taken. Such observations made it possible to determine the velocity distribution in different spots.

A preliminary reduction of the material revealed some interesting features. Thus a close connection between the intensity of the umbra and the magnitude of the Evershed effect was indicated. Large sunspots usually have low umbra intensities, and also show the largest Evershed velocities, a conclusion earlier pointed out by Michard.

On three occasions rather large Doppler displacements were found: May 11, June 7 and June 17, 1960. Maximum velocity in the line of sight was 5.5; 5.0; and 4,5 km/sec, respectively.

A paper reporting these preliminary results is in the process of being printed in "Annales d'Astrophysique" under the title "NOTE ON THE EVERSHED EFFECT IN SUNSPOTS".

IV. RESEARCHES ON PROMINENCES, PLAGES AND SOLAR TEMPERATURE

1. Temperature conditions and the state of excitation of helium in prominences

A comprehensive study of physical conditions in prominences was started by Tandberg-Hanssen during his stay at the High Altitude Observatory of the University of Colorado, sponsored by Air Force Contract AF 19(604)-2140 with that Observatory. The work was completed after Tandberg-Hanssen's return to Oslo, and then sponsored by the present Air Force Contract. The finished paper:

"AN INVESTIGATION OF THE TEMPERATURE CONDITIONS IN PROMINENCES WITH A SPECIAL STUDY OF THE EXCITATION OF HELIUM"

was printed in Astrophysica Norvegica Vol. VI, No 14, 1960, and was accepted by Oslo University as a thesis for the degree of Doctor Philosophiae. It was issued from this institute as Scientific Report No 6.

2. Plage spectra

The scarcity of spectral information on plage areas is very apparent, and has rendered the analysis of plage physics difficult. The nature of plages constitutes an interesting topic for research, and for several reasons. Thus many flares brighten up in pre-existing plage regions, and plages always precede the formation of a sunspot. There is, further, a close correlation between plages and the intensity of centimeter and decimeter wave emission from the chromosphere.

Tandberg-Hanssen has made exploratory tests for the use of the horizontal spectrograph of the Solar Observatory for spectroscopy of plages. The first spectra were taken last summer, with the emphasis on the extreme blue part of the spectrum (around 4000 Å). Kodak 103a plates were used, and a Zeiss stop attenuator inserted to calibrate the plates against the normal photospheric spectrum. A comparison of the results with the Utrecht Solar Atlas for the normal solar spectrum indicates that the spectrograph may be well suited for such work. It gives good line profiles with three prisms in autocollimation, dispersion about 0.3 Å/mm at 4000 Å.

To get reliable comparison spectra of the adjacent undisturbed photosphere one needs an exposure timer, which now is being built in the shop. As soon as this instrument is available, the observational work will be started.

3. Pole-equator variation of temperature in the sun:

This age-old problem seems never to be answered in a manner acceptable to the scientific mind, and has led to new attacks on the problem along many different routes. The use of the pinhole photometer for sunspot studies gave Maltby the idea to test the variation of solar temperature over the disk on using this instrument.

The carrying out of this project involves many delicate points and pitfalls, but all in all it seems that the pinhole photometer used for this purpose is competitive with other methods of approach.

Maltby summarized his experiences in this field in a short paper:

"A SEARCH FOR DIFFERENCES IN TEMPERATURE BETWEEN THE POLES AND THE EQUATOR OF THE SUN",

Astrophysica Norvegia, Vol. VII, No 3, 1960.

He failed to find a systematic variation of temperature from pole to equator on the sun, and concluded that if such a difference exists, it is less than 20 °C.

V. INSTRUMENTAL DESIGNS

1. Rotating disk shutter for solar photography

A shutter of novel design for solar work was developed by Brekke for the most part under the preceding contract and reported on in the appropriate "Technical (Final) Report" of January 21, 1959. The detailed description of the instrument in a technical report fell, however, within the scope of the present contract, and it appeared as Scientific Report No 1:

"A HIGH SPEED ROTATING DISK SHUTTER FOR PHOTOGRAPHING THE SOLAR DISK". ITA Report No. 5, 1959.

2. The isophotal planimeter

Eriksen has, during the contract period, completed the design and construction of an "isophotal planimeter", which works as follows: The flying spot of a 5FP15 cathode-ray tube describes a square raster (6x6 cm) composed of 400 horizontal lines. One scan is completed in 8 seconds. The raster is projected on a reduced scale (adjustable between 5:1 and 20:1) by means of a beam-splitting mirror and objective lenses onto

A. the photographic film to be investigated followed by a calibrated density wedge,

and

B. a reference density film.

The light from the scanning spot passing through the two optical channels is picked up by two photomultiplier tubes: "the signal cell", and "the reference cell".

Whenever the light spot illuminates a portion of the negative-and-wedge combination having a lower density than the reference density, the output voltage difference from the cells operates a trigger circuit which unblanks a second cathode-ray tube which operates from the same sweep generators as the scanning tube.

The indicator exhibits an illuminated surface which is an enlargement (5-20 times) of that part of the photographic negative having a transparency above the level selected by means of the calibrated wedge. By differentiating the difference voltage before applying it to the trigger, the indicator will show the contour of the transparent surface. Thus an isophote has been drawn.

Different isophotes may be selected by different settings of the calibrated wedge.

The area within a closed isophote can be measured by means of a multi-decade electronic counter, fed by a pulse generator controlled by the difference voltage.

This instrument has been found to work very well, and has already been put into use on various project. A complete technical description of it will in due time appear as a separate technical report of the contract.

VI. LIST OF SCIENTIFIC REPORTS COMPLETED AND PARTLY PUBLISHED UNDER Contract AF 61(052)-186

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Sc. Rep.	Author:	Title:	References:
No 1.	Kjell Brekke:	A HIGH SPEED ROTATING DISK SHUTTER FOR PHOTOGRAPHING THE SOLAR DISK	ITA Report No 5, Oslo 1959
2.	Odd Steen, Per Maltby:	ON THE CORRELATION BETWEEN OBSERVATIONS OF MAGNETIC FIELDS OF SUNSPOTS AT MT. WILSON, POTSDAM AND THE CRIMEA	Astrophys. Norv. Vol. VI, No 10, 1959
3.	Öystein Elgaröy:	1. FREQUENCY DRIFT AND FINE STRUCTURE OF 200 Mc/s SOLAR BURSTS	IAU Symposium 1959 Paper 47
		2. OBSERVATIONS OF THE FINE STRUCTURE OF ENHANCED SOLAR RADIATION WITH A NARROW-BAND SPECTRUM ANALYZER	NATURE, Vol. 184, 887, Sept. 19, 1959
4.	Öivind Hauge:	VARIATIONS IN THE SOLAR BASE LEVEL RADIATION ON 200 Mc/s	Astrophys. Norv., Vol. VI, No 11, 1960
5.	Per Maltby:	DISTRIBUTION OF ORIGIN AND DECAY OF NOISE STORMS ON THE SOLAR DISK	Astrophys. Norv., Vol. VI, No 13, 1960
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